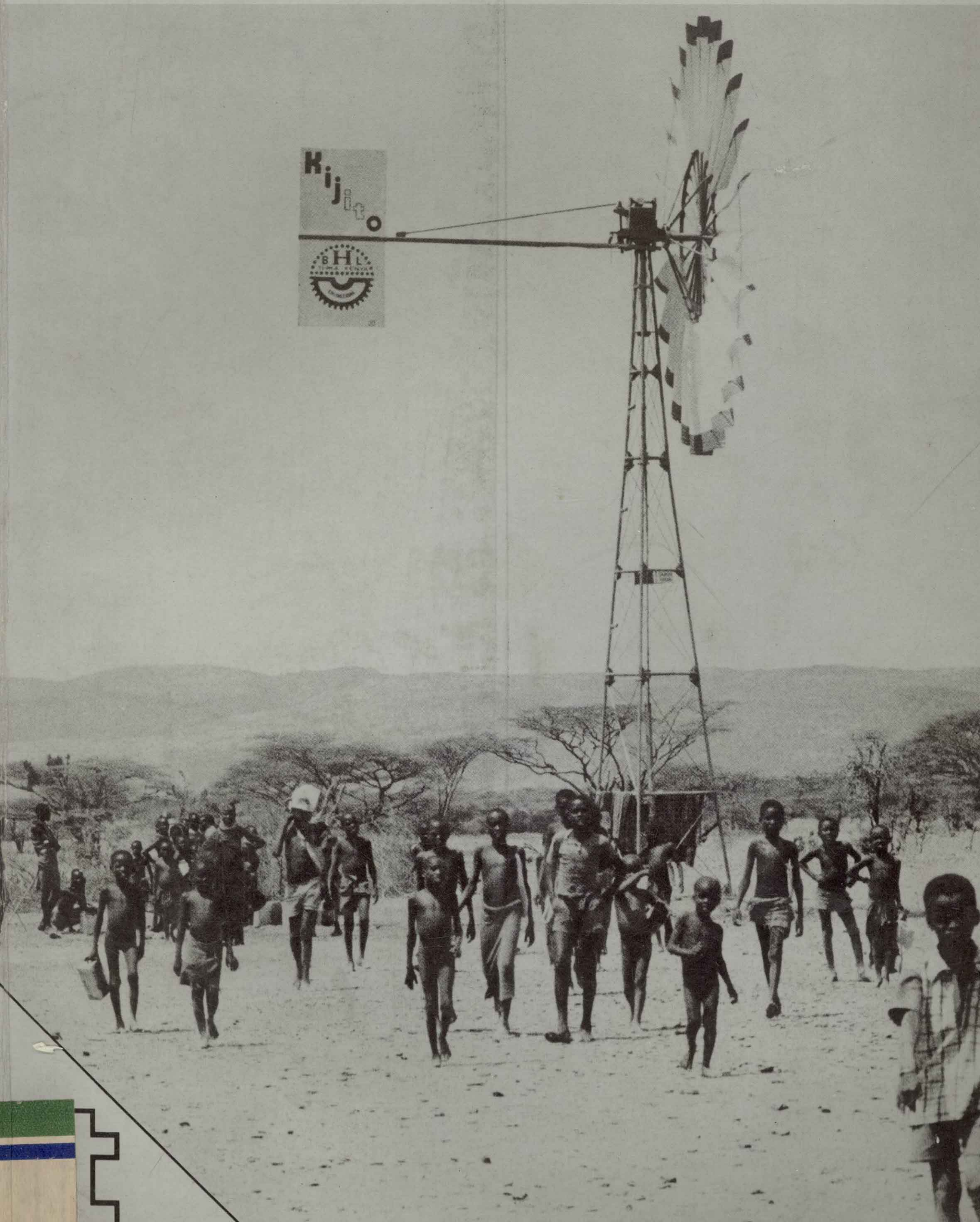
WINDPUMPING HANDBOOK

Sarah Lancashire, Jeff Kenna and Peter Fraenkel



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Preface

Windpumping is an established technology, with over one million windpumps in use worldwide. A windpump needs no fuel, little maintenance and it usually lasts 20 years or more. Designs exist which are suitable for small-scale local manufacture. The aim of this handbook is to help potential users and decision makers take advantage of the benefits that windpumps can offer.

This handbook was first written for a windpump familiarisation seminar held in Nairobi in November 1986. The seminar was organised and presented by I.T. Power, hosted by the Ministry of Water Development of Kenya and funded by the Overseas Development Administration.

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CHAPTER 1: INTRODUCTION

1.1 Purpose of this Handbook

Water for people, animals and crop irrigation is an essential need in every country. Frequently this water has to be pumped from the ground; the pumping requires energy. In rural areas this energy has traditionally been provided by people operating hand pumps or animal pumps. Where mechanized power is available it is most commonly an internal combustion engine burning petrol or diesel oil. Recently there has been a growing interest in the new technology of solar-powered water pumps and a revival of interest in windpumps.

There are many good windpump designs, both traditional and modern lighter weight ones, currently available. These machines have high performance and good reliability. The purpose of this Handbook is to provide decision-makers and potential users of windpumps with the basic information on present-day:

- windpump technology
- economics
- sizing to meet domestic or irrigation demand
- procurement
- installation
- maintenance.

It has been assumed throughout the Handbook that the reader is familiar with the basic concepts and units of energy, power, flow, density, etc. A comprehensive bibliography is appended for those readers who wish to study windpumps in greater depth.

1.2 Windpump technology is time-proven

A brief history of windpumps

The ancient Egyptians used wind power 5000 years ago to propel boats. It is uncertain when wind power was first used on land to power rotating machinery but it is estimated to be about 2000 years ago. Historical records show that windmills definitely existed in 200 BC in the area now known as eastern Iran and western Afghanistan. This area receives constant winds from the steppes of Central Asia during and after harvest time each year, called the "Wind of a Hundred Days". The Chinese have used windmills for low lift paddy irrigation for many centuries.

About 1000 years ago horizontal-axis sail windmills were being used around the Mediterranean. By the 12th century windmills had reached northern Europe. They became an important part of the industry of both Britain and the Netherlands in the centuries that followed. In Britain they were mostly used for milling grain; in the Netherlands many were used for dewatering polderland.

By the 18th century windmills were one of the highest forms of technology. They could produce 30-40 kW of power (which is about the same as the power of a small motor car). With the advent of steam power and later the internal combustion engine in Europe, the incentive to develop windmills disappeared. Instead, windmill development continued in the USA. In the mid 19th century settlers were moving into the Great Plains where there was a shortage of fuel and transport was difficult. With the need for water and the steady, regular wind across the Great Plains, windmills were an ideal technology. By the 1880's the familiar all-steel American multi-bladed farm windpump had evolved. It looked not much different from many that are still in production today.

Past experience which has led to the adoption of present-day windpump designs

Most modern efficient windpumps are horizontal axis, multi-bladed (see Figure 1). Other designs have been tried in the past and have proved less satisfactory for water pumping. They are briefly described below:

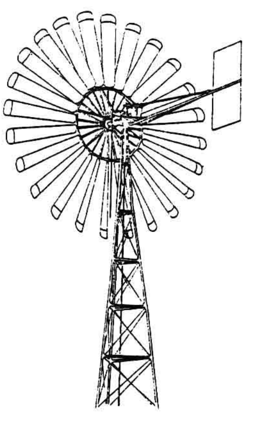


Figure 1:

Multi-bladed horizontal-axis windmill (side view)

2- or 3- bladed horizontal-axis windmills are used for electricity generation. They are not suitable for water pumping directly because

1. they cannot produce enough torque to start a piston pump working; and

2. they rotate too quickly to directly drive a reciprocating pump. These wind turbines are also more difficult to manufacture owing to the precision engineering needed.

However they could be used indirectly for water pumping by generating electricity and using this to drive electric pumps. This option is expensive but may be suitable for some locations or when a large amount of power is needed.

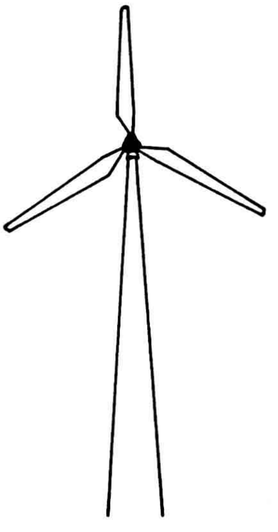


Figure 2: Three-bladed horizontal-axis windmill (side view)

Savonius rotors are turned by the drag force of the wind mostly, rather than the lift force. They are therefore inefficient and turn very slowly. (See Sections 1.3 and 2.1 for explanations of drag and lift forces).

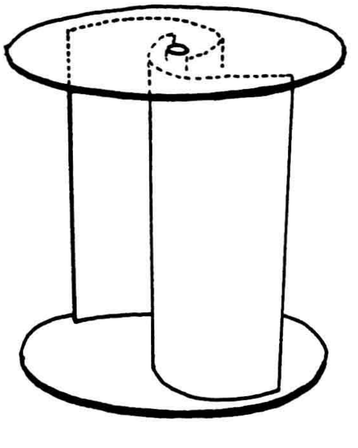
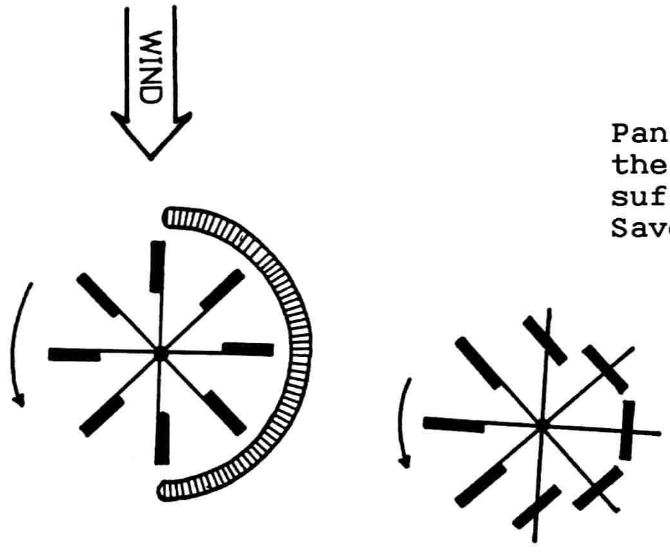


Figure 3: Schematic diagram of Savonius rotor (side view)



Panamones are turned entirely by the drag force of the wind. They suffer the same disadvantages as Savonius rotors.

Figure 4: Panamones (plan views)

Cross flow or Darrieus wind turbines are attracting some attention at present. However they are unsuitable for water pumping because they cannot normally self-start. Even if they are modified to enable them to self-start they cannot produce sufficient torque to start a pump. They are difficult to protect from storm damage and have not yet been manufactured more cheaply than horizontal-axis rotors.

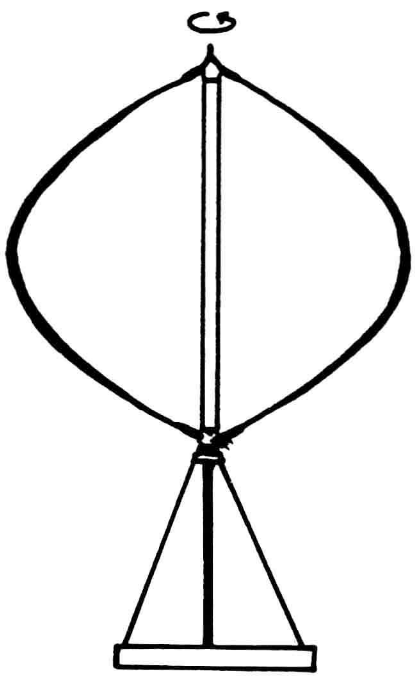


Figure 5: Schematic diagram of Darrieus wind turbine (side view)

The remainder of this Handbook concentrates on multi-bladed horizontal-axis windpumps as the only practical, commercially-available technology for water pumping at this time.

1.3 The wind energy resource

Many areas of the world are sufficiently windy for windpumps to be a realistic option for pumping water. Figure 6 shows a contour map of the average annual wind speeds for the world (Reference 1). It must be remembered that, in general, the basic requirement for wind to be a reasonable option for water pumping is that the average wind speed in the most critical month (i.e. the month where the demand for water is greatest in relation to the wind energy available) is greater than 2.5 m/s (6 mph or 5 knots). The wind will vary from day to day and month to month. It is important that there is sufficient wind available <u>throughout</u> the period when water is needed. If the water is for irrigation it may be needed for only a few months, but if the water is for domestic consumption, there must be sufficient wind all year. It is advantageous to have reliable windspeed data for at least a year to decide firstly whether a windpump is a possible option, and secondly what size of windpump to use, and how much water storage is needed.

This section briefly explains how to determine the energy available from the wind if the wind speed is known. Section 3.1 will explain how, where and how often to measure wind speeds.

The effect of wind speed

The power in the wind, and therefore its energy,is proportional to the cube of the wind velocity. This means that as the wind speed increases, the power available increases much faster. For example, in very light winds there is about 10 W/m^2 whilst in hurricane-level winds there is about 40,000 W/m^2 . This extreme variability of the wind power strongly influences most aspects of system design, construction, siting, use and economy. In comparison, the solar energy resource is much less variable, there being about 100 W/m^2 in weak sunshine and 1000 W/m^2 in the strongest sunshine.

The equation describing the power in the wind is:

$$\boxed{\text{Power in W}} = \boxed{1/2} \times \boxed{\text{Density of air in kg/m}^3} \times \boxed{\text{Cross-sectional area in m}^2} \times \boxed{(\text{Velocity})^3 \text{ in m/s}}$$

The effect of air density

The density of the air affects the energy available to a very much lesser extent than the wind velocity. However it should not be ignored. The density of the air is affected by:

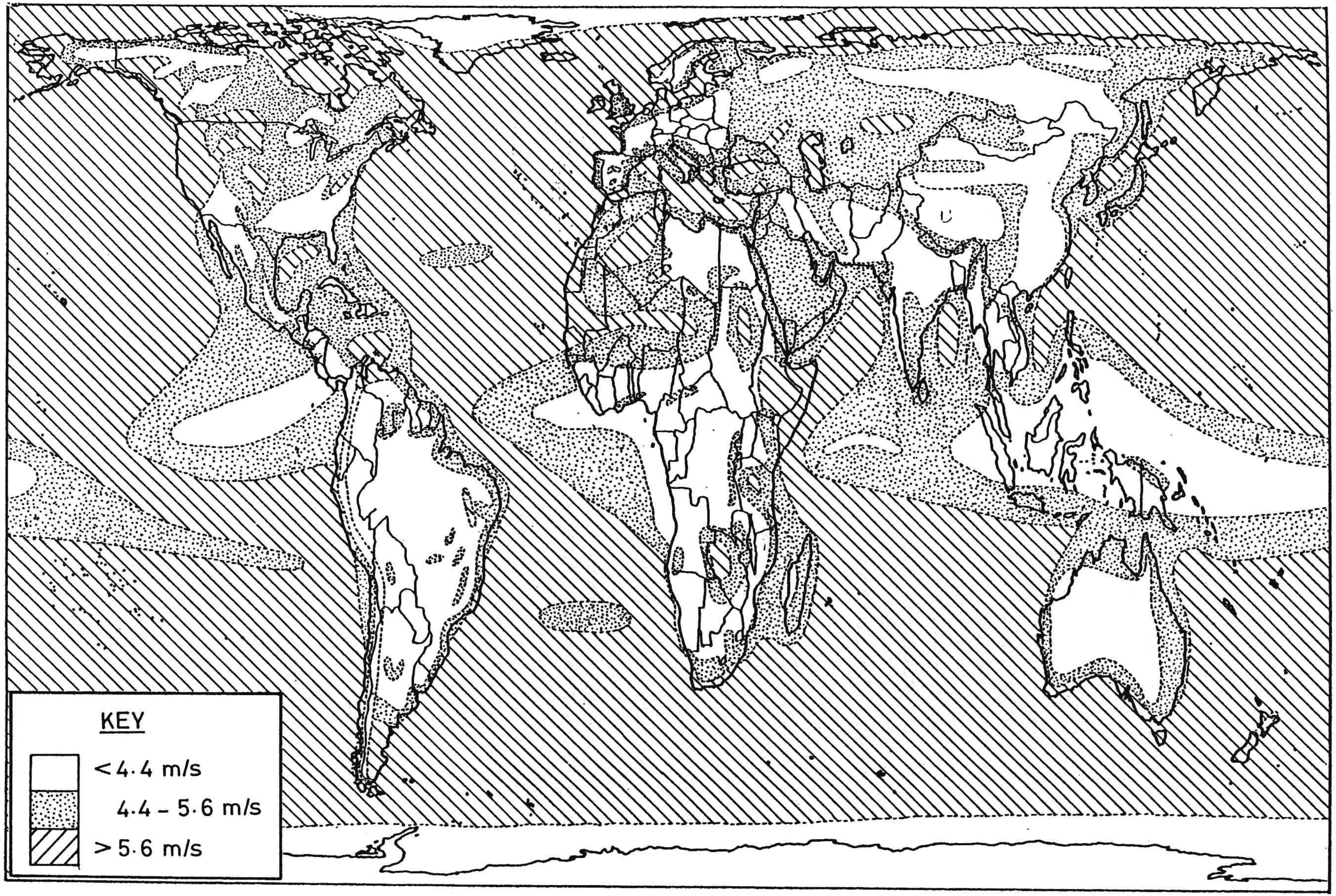


Figure 6: Global annual average wind speeds. (Redrawn from World Meteorological Society data in WMO Technical Note on Wind Energy. Reference 1)

Note - Very large local variations occur in wind speeds. This map should not be used for windpump siting. It is included to give a general indication only.

1. altitude
2. temperature
3. atmospheric pressure.

The effects of temperature and atmospheric pressure are very small compared with altitude and may therefore be ignored. Allowance should be made for altitude, however. For example at an altitude of 1000 metres the energy available from the wind at a given wind speed is reduced by 11%.

Table 1 gives the altitude correction factors which should be applied to the air density in order to calculate the available wind energy. Air density at sea level is 1.2kg/m^3. Figure 7 shows the same information graphically on an energy-versus-wind speed graph.

Altitude in metres above sea level	0	1000	2000	3000
Air density correction factor	1.00	0.89	0.78	0.69

Table 1: Altitude correction factors for air density

Example: To find the air density at 2000 m

Air density at 2000 m	=	Air density at sea level	x	Correction factor

Air density at 2000 m = 1.2 x 0.78

= 0.94 kg/m^3

However, the wind tends to blow at higher speeds at higher altitudes. This often more than compensates for the loss due to reduced air density.

Energy availability

Only part of the energy in the wind is available for use. To extract all the energy would require bringing the wind to rest which is impossible. The available energy is extracted by slowing down the wind and using some of its kinetic energy. The maximum amount of energy that can, even in theory, be physically extracted from the wind is 59.3% of the total available. In practice wind rotors are not perfectly efficient. Good ones will be able to extract 25-40% of the total kinetic energy.

To find the amount of energy available from the wind

The graph in figure 7 may be used to find out the amount of energy that is obtainable from the wind by a well-designed windpump in a typical wind regime.

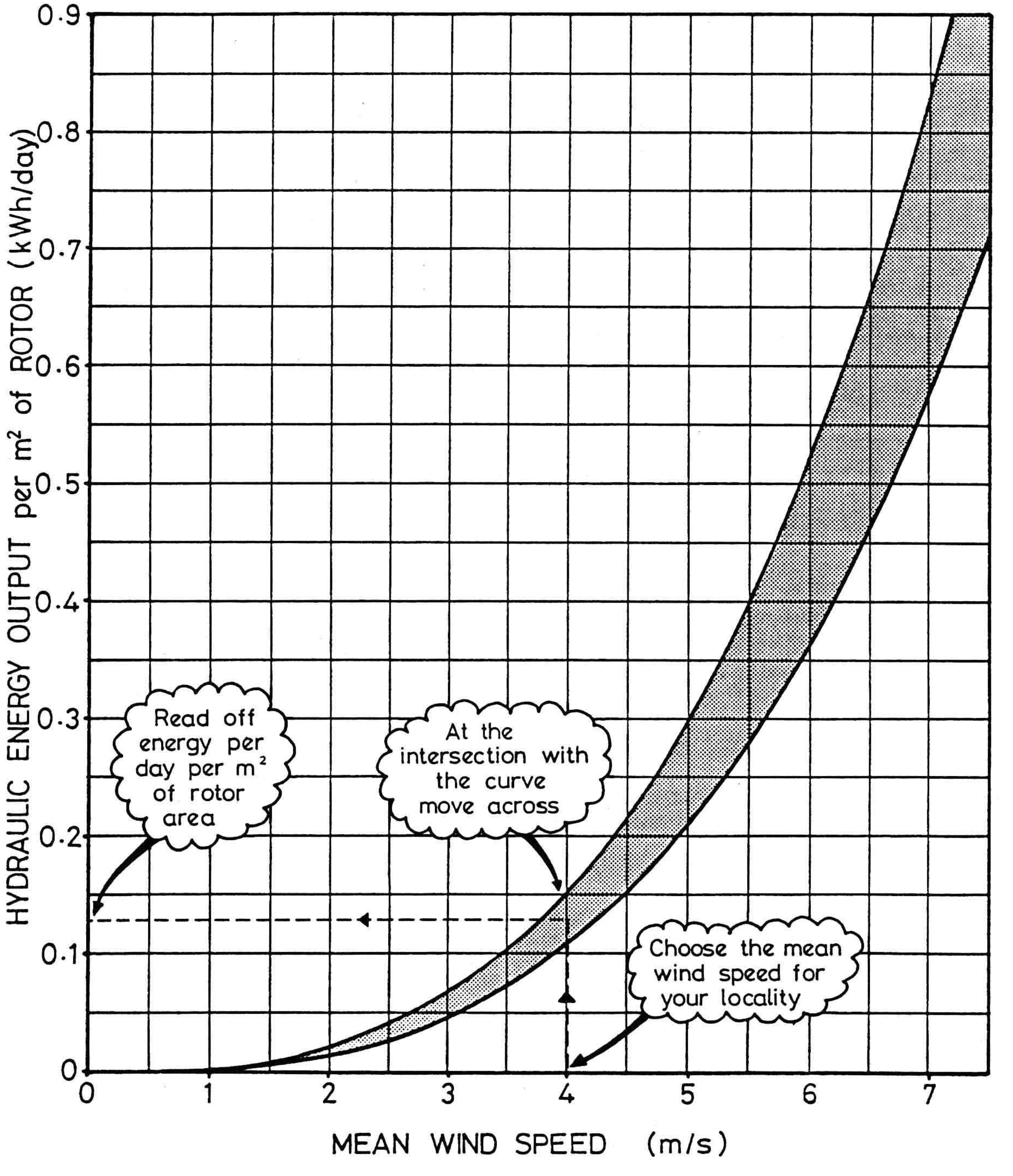


Figure 7: Approximate hydraulic energy output of a windpump rotor for various wind speeds